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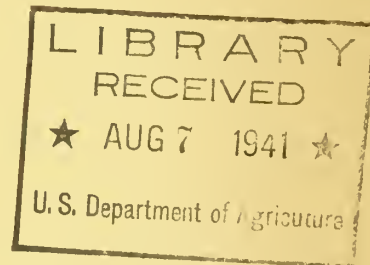
UNITED STATES DEPARTMENT OF AGRICULTURE
Bureau of Agricultural Economics

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USE OF FARM TRACTORS IN MINNESOTA



By Truman R. Nodland and A. J. Schwantes, University of Minnesota,
and Ross V. Baumann, Bureau of Agricultural Economics

Washington, D. C.

November 1940

ACKNOWLEDGMENT

The authors wish to acknowledge the help of Frank T. Hady and George A. Pond in planning the study, supervising the gathering of the data, and making suggestions for improving the manuscript. Sherman E. Johnson, C. W. Crickman, B. R. Hurt of the Bureau of Agricultural Economics, and S. A. Engene of the Minnesota Agricultural Experiment Station made many helpful criticisms and suggestions.

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INTRODUCTION

The place of tractors as a source of power on Minnesota farms is increasing at the rate of 2 or 3 percent a year. In 1938, 40 percent of the available drawbar power was in the form of tractors. 2/ This proportion of power was provided by 36,288 tractors. 3/ In addition 695,000 horses and mules were used, an average of 4 horses and one-half tractor per farm.

1/ Assistance in the preparation of these materials was furnished by the personnel of the Work Projects Administration, Official Project No. 65-1-71-140, Subproject No. 461, Sponsor, University of Minnesota.

2/ Assuming tractor drawbar horsepower equivalent to 0.6 horse drawbar power.

3/ Implement and Tractor, Implement Trade Journal Company, Kansas City, August 6, 1938.

The greatest number of tractors per 100 farms in 1938 were found in Wabasha, Goodhue, Nicollet, Ramsey, Watonwan, Lyon, Wilkin, and Kittson Counties (fig. 1). 4/ Ramsey County had a large number of tractors per 100 farms because of the use of garden tractors in the vicinity of the Twin Cities. Few tractors were found in the cut-over areas and in counties with light soils. Much less farm power is required where self-sufficing agriculture predominates. Incomes are low and little cash is available for buying a tractor or tractor fuel. Abundant pasture and hay make horses a cheap source of power.

The number of tractors per 1,000 acres of land available for crops was similar in distribution (fig. 2). Concentration in some of the southeastern counties was relatively high. Land available for crops in these counties is somewhat small compared with total land in farms, yet a large proportion of the farmers own tractors. The small proportion of total farm land available for crops and the fact that there are more tractors in the region than are needed for farm work account for the heavy concentration of tractors in the northeastern part of the State. Tractors are also used for land clearing, lumbering, and road work.

PURPOSE AND EXTENT OF STUDY

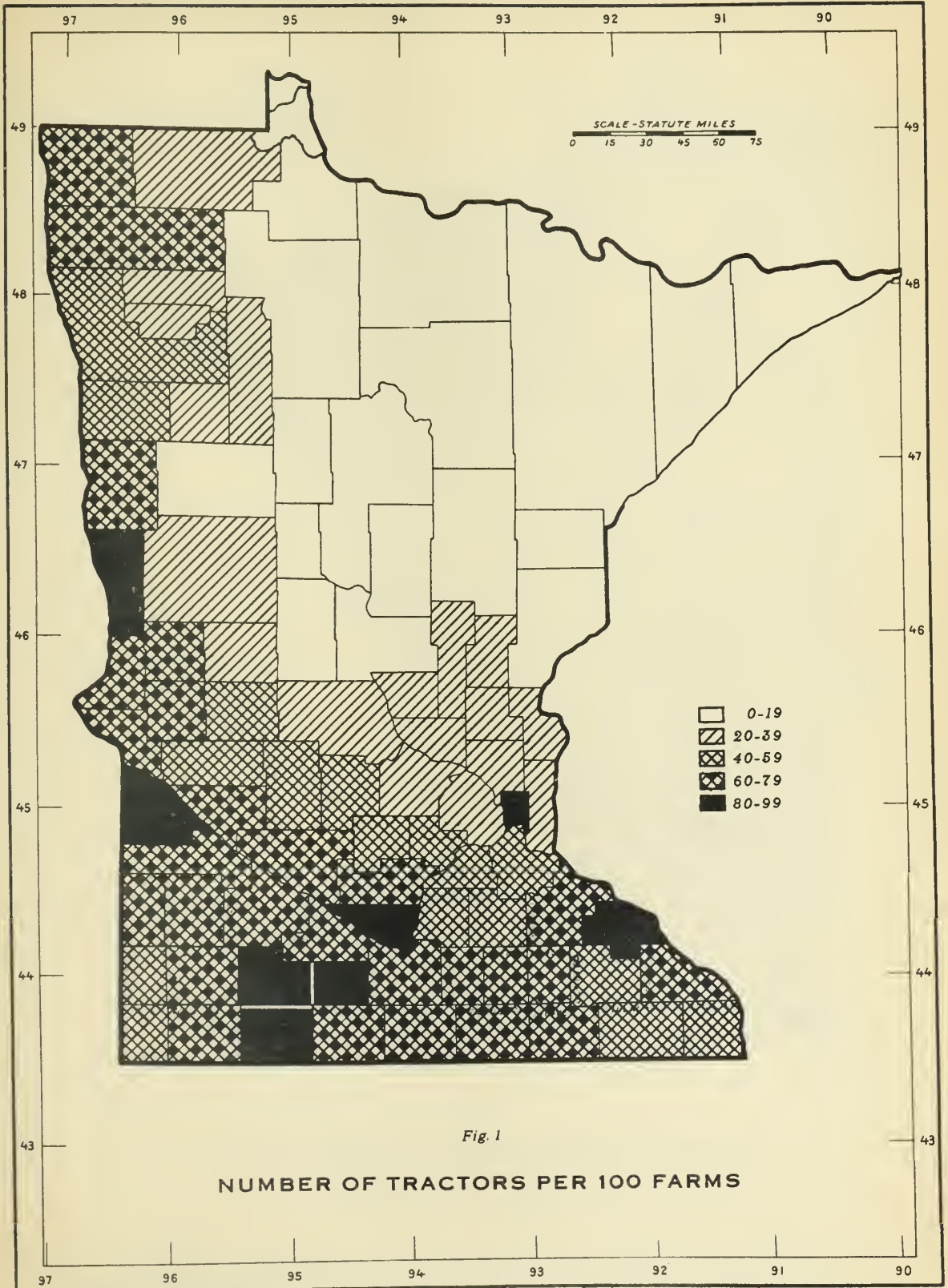
To learn the experiences of farmers in the use of various sizes and types of tractors with the machinery and equipment available on their farms, 581 individual farm-survey records, covering the operations of 709 tractors, were obtained in 1939 as of April 1. 5/ The locations of the farms from which records were obtained are indicated in figure 3. These farms were typical of those using tractors in the major type-of-farming areas of Minnesota. The number of farms and tractors covered in each area are shown in table 1. Where two or more tractors were used on a farm, a record of the operations performed by each tractor was obtained.

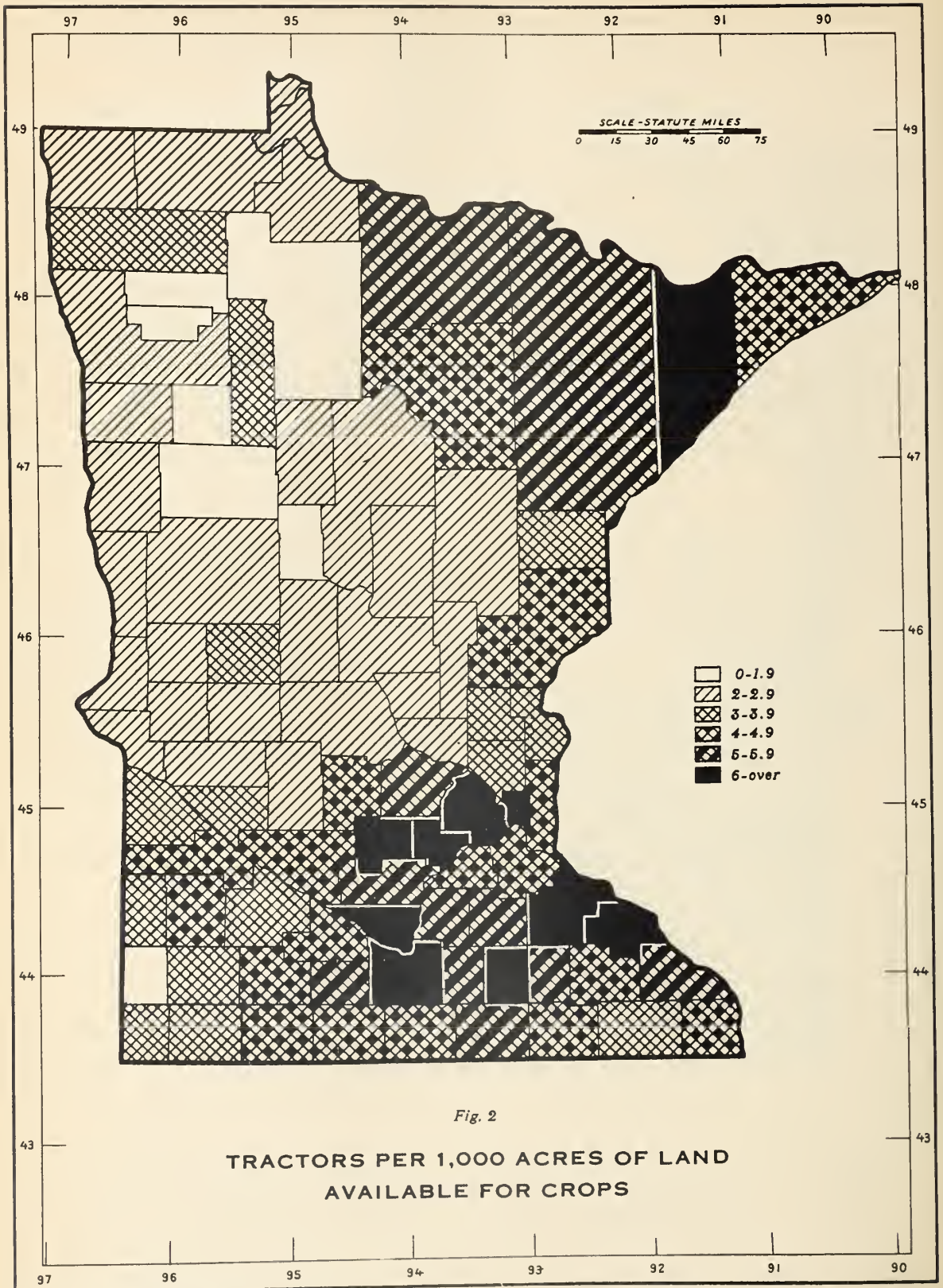
Table 1. — Number of farms and tractors studied and proportion of all-purpose tractors, by areas

	Area				Red	
	South	South	South	West	River	All
	East	Central	West	Central	Valley	Areas
	Number	Number	Number	Number	Number	Number
Farms studied	68	84	161	139	129	581
Tractors studied	79	101	182	157	190	709
	Percent	Percent	Percent	Percent	Percent	Percent
All-purpose tractors	56	72	34	36	52	71

4/ Kirk, Paul H., Minnesota Crop and Livestock Statistics. Minnesota Department of Agriculture and U.S.D.A., Bur. Agr. Econ.

5/ This is one of two reports on the results of this survey. The other, prepared by Ross V. Baumann, Truman Modland, and George A. Pond, is called "The Tractor and Its Effects on Farming in Minnesota." (Processed.)





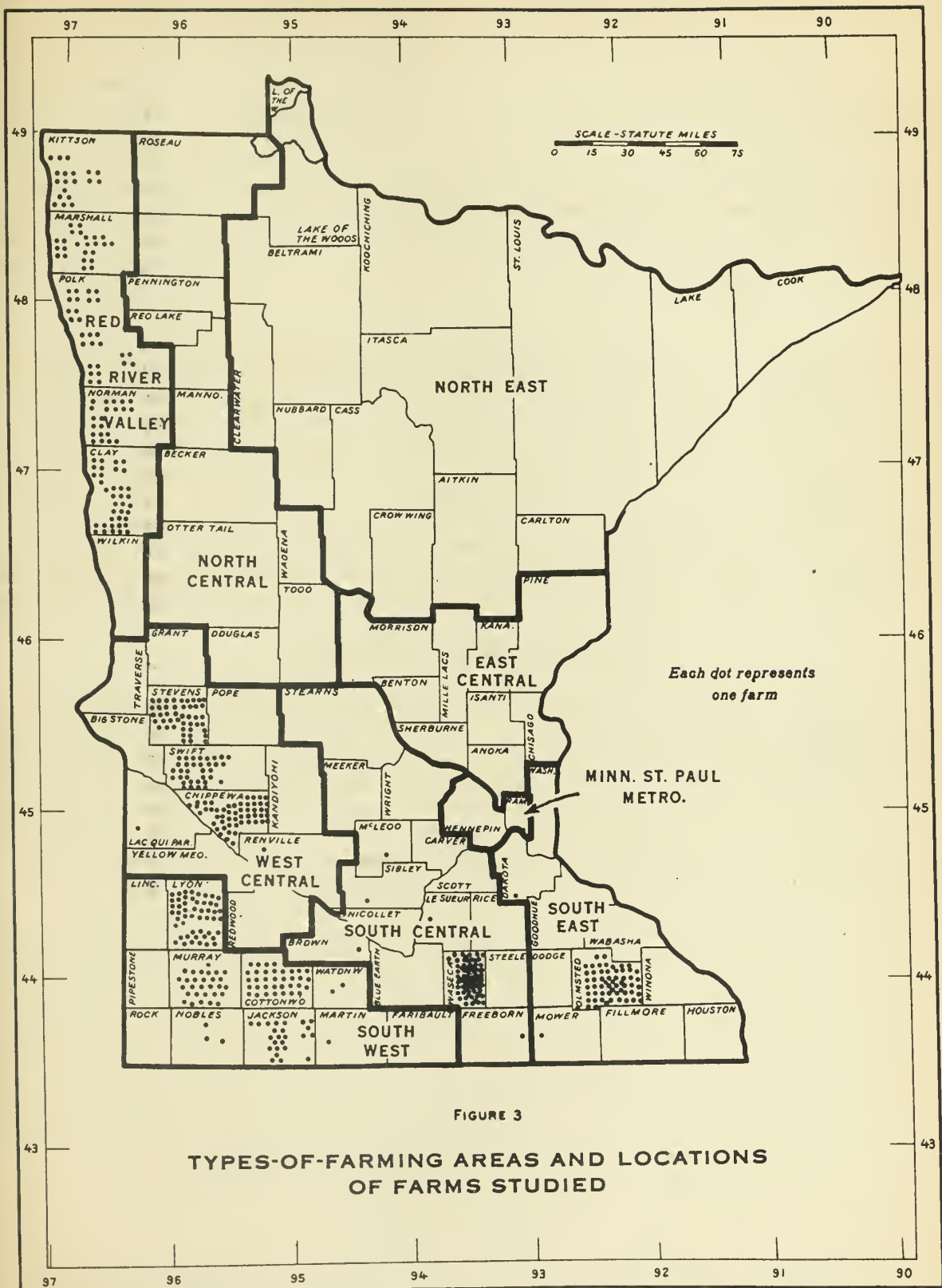


FIGURE 3
TYPES-OF-FARMING AREAS AND LOCATIONS
OF FARMS STUDIED

POWER SUPPLY ON FARMS STUDIED

Measuring Size and Capacity of Tractors

The power of a tractor commonly has been expressed by the number of moldboard-plow bottoms the tractor will handle satisfactorily under average conditions. A tractor capable of pulling a two-bottom plow is referred to as a two-plow tractor. This designation is not always precise, because the power required for a plow may vary considerably. Another disadvantage is that all moldboard plows are not the same size. Plows with 14- and 16-inch widths predominate, but 12- and 18-inch widths are also used. Obviously, other things being equal, more power is required to pull two 16-inch bottoms than two 14-inch bottoms.

A more adequate method of expressing the power of a tractor is by the horsepower that it develops under controlled conditions. The University of Nebraska has set up standard procedures for measuring the drawbar and belt horsepower of tractors. Results of these tests are used as a basis for assigning to the tractor a highest-permissible rating for drawbar and belt power, according to the recommendations of the Farm Tractor Rating Code of the American Society of Agricultural Engineers and the Society of Automotive Engineers. Most manufacturers now use the highest-permissible rating when stating the horsepower of their tractors. For drawbar work, the rating does not exceed 75 percent of the maximum drawbar power which a tractor will develop at the rate of travel recommended for the ordinary operation of the tractor.

Number and Size of Tractors

In this report, the tractors have been classified on the basis of their rated drawbar horsepower. Only the drawbar rating was used, for most tractors are bought primarily for drawbar work. The tractors are classified into groups, each group having a range of 5.5 horsepower. In Group I are those tractors with a rating between 5.5 and 11.99 horsepower, in Group II those with a rating between 12.0 and 18.49 horsepower, in Group III those with a rating between 18.5 and 24.99 horsepower, and in Group IV those with a rating between 25.0 and 31.49 horsepower, and so on for succeeding groups.

Table 2. -- Number of tractors on selected Minnesota farms and their distribution by rated drawbar horsepower,^{1/} by areas

Item or drawbar horsepower group	Area				
	South	South	South	West	Red
	East	Central	West	Central	River ^{2/} Valley
Number of farms studied	68	84	161	139	129
Number of tractors	79	101	182	157	190
Group I, percent	46	39	32	39	25
Group II, percent	46	46	62	53	46
Group III, percent	4	9	5	7	16
Group IV, percent	4	6	1	1	10

^{1/} Group I includes tractors with a drawbar rating between 5.5 and 11.99; Group II, 12.0 and 18.49; Group III, 18.5 and 24.99; Group IV, 25.0 and 31.49.

^{2/} Besides these groups in this area there were four tractors in Group V and one in Group VIII. These five tractors are included in the total of 190 for the area.

Thirty-four percent of all tractors were included in Group I. Most of the tractors of this group are those commonly spoken of as one-plow tractors, while those in Group II are of the size commonly known as two-plow tractors. Over half of all of the tractors were in Group II. The small tractors were most prevalent in the South East area where 46 percent of all tractors were in Group I. The South Central and West Central areas each had 39 percent in Group I, and in the Red River Valley area only one-fourth of the tractors were in this group. Large tractors were more prevalent in the Red River Valley where 29 percent had rated drawbar horsepower of 18.5 or more; however, in all areas, except the South East, tractors with a rated drawbar horsepower of between 12.0 and 18.49 were most common.

Total Drawbar Power

The horse equivalent per farm of total available drawbar power was about 13.5 in all areas studied except the Red River Valley, where it amounted to 18.5 (table 3). The average number of horses per farm in each area and the estimated horse equivalent of tractor drawbar power indicate that horses represent over one-fourth of the available power on these tractor farms. Of the 581 farmers interviewed, 19 kept no horses, 6 kept only one horse, 130 two horses, and the other 426 kept three or more. The largest number of horses reported on a single farm was 18, on a farm of 2,240 acres located in the Red River Valley. Four tractors were used in addition to the horses on this farm.

Table 3. — Total available drawbar power per tractor farm studied, by areas

Item	Area				
	South East	South Central	South West	West Central	Red River Valley
Crop acres per farm	151.0	166.0	217.0	261.0	378.0
Work horses per farm	4.1	4.7	4.1	3.7	4.3
Average tractor-drawbar horsepower per farm <u>1/</u>	15.5	16.6	15.2	15.1	23.7
Average horse equivalent of tractor-drawbar horsepower <u>2/</u>	9.3	10.0	9.1	9.1	14.2
Total farm drawbar horse- power in horse equiva- lents	13.4	14.7	13.2	12.8	13.5
Crop acres per horse equivalent <u>3/</u>	11.3	11.3	16.4	20.4	20.4

1/ Only tractors used for field work included.

2/ Computed by taking 0.6 of the rated drawbar horsepower of tractors used for field work.

3/ All farm power.

One hundred and twelve farmers, or 19 percent, had more than one tractor. Fifteen percent of the farmers in the South East area, 21 percent in the South Central area, 12 percent in the South West area, 11 percent in the West Central area, and 37 percent in the Red River Valley area had two tractors. Thirteen farmers had as many as three tractors. Only three farmers had four tractors.

Age of Tractors

Over three-fourths of the tractors on the 581 farms in 1939 had been bought in 1934 or later. In other words, they have been operated four years or less. Many factors contributed to the recent acquisition of new tractors. Farm prices had been more favorable since 1935 than for the years immediately before that date. Sleeping sickness of horses and hot summers have reduced horse numbers or decreased their effectiveness. Recent improvements in all-purpose types, rubber tires, higher speeds, and smaller sizes have extended the use of tractors. These improvements have made easier the complete mechanization of operations.

Table 4. — Distribution of tractors by year of purchase by areas

Year of Purchase	Area				
	South East	South Central	South West	West Central	Red River Valley
	Percent	Percent	Percent	Percent	Percent
1933 - March 1939	15	18	24	20	26
1936 - 1937	26	43	48	37	30
1934 - 1935	9	15	14	19	23
1932 - 1933	4	5	0	5	5
1930 - 1931	11	4	4	5	6
1928 - 1929	25	7	7	8	5
1926 - 1927	5	2	1	3	3
1925 - and before	5	6	2	3	2

Approximately 80 percent of all tractors studied had been bought new. Little variation was found between areas in this respect. Three-fourths of the tractors in the South East and Red River Valley areas were bought new, 85 percent in the South Central and South West areas, and 81 percent in the West Central area. Fourteen different makes of tractors were reported. One tractor primarily used for corn cultivating was home-made.

Type of Fuel Used

Most tractors were operated with only one kind of fuel but, whatever fuel was used, gasoline was always used for starting. One-half of the tractors studied were operated with gasoline exclusively, while one-third were used with distillate. The other tractors were used with gasoline for some

Table 5. -- Distribution of tractors by type of fuel that was used. 1/

Type of fuel used	Number of tractors	Percent of all tractors
Gasoline exclusively	354	50
Kerosene exclusively	17	2
Distillate exclusively <u>2/</u>	224	32
Gasoline and distillate	63	9
Gasoline and kerosene	26	4
Kerosene and distillate	<u>24</u>	<u>3</u>
Total number	708	100

1/ Based on 708 reports

2/ Includes fuels below the grade of kerosene that were used in spark-ignition engines.

work and kerosene or distillate for other jobs. Kerosene was used in very few tractors as the sole fuel.

Kerosene has been largely replaced by gasoline and distillate in this work in recent years because it has been almost as expensive as gasoline in most communities, and has lower anti-knock qualities. Moreover, distillate or so-called tractor fuel has been improved to make it more satisfactory and dependable while its price has been lower than the price of kerosene.

No attempt was made in this study to ascertain the number of tractors with high-compression engines requiring gasoline. Gasoline is used more efficiently in such engines than in those with lower compression ratios in which kerosene or distillate can be burned. Doubtless, an appreciable number of those tractors for which the use of gasoline only was reported were equipped with high-compression engines.

SPECIAL EQUIPMENT AND ACCESSORIES

Over one-third of the wheel-type tractors studied had rubber tires on the rear wheels. Recent purchases indicate that 80 to 90 percent of all tractors are equipped with rubber tires. This, together with the fact that farmers are equipping their steel-wheeled tractors with rubber, indicates that rubber tires are being widely used. Over one-half of the tractors studied also had rubber tires on the front wheels. Rubber tires on the front wheels relieve a considerable proportion of the shock experienced in operating tractors and they aid in the steering.

Table 6.- Tractors equipped with rubber tires by drawbar-horsepower groups, by areas

Item or drawbar-horsepower group	:South: :East	South :Central	:South :West	:West :Central	:Red River :Valley
	Number	Number	Number	Number	Number
Tractors with tires on front wheels:	38	50	121	87	79
Tractors with tires on rear wheels:					
by size groups. ^{1/}					
Group I	14	10	24	9	12
Group II	19	23	48	27	39
Group III	0	3	5	4	9
Group IV	1	1	0	0	3
Total Number	34	37	77	40	63

^{1/} See Table 2, footnote 1, for explanation of tractor size groups.

The group of tractors of a rated drawbar horsepower of between 12.0 and 18.49 horsepower contained the largest proportion of tractors with rubber tires. The use of rubber tires increases the amount of work obtained from a given quantity of fuel and makes possible higher speeds.

Frequently dead weight is added to the tractor drive wheels to increase traction. One-third of the rubber-tired tractors had cast-iron or concrete devices attached to the wheels, and one-third used liquid in the tires. Frequently, greater traction is obtained in the drawbar work itself, when the resistance tends to pull the rear end of the tractor to the ground, as in plowing.

Many accessories are becoming standard equipment on tractors. The belt pulley is common on all types, but the power lift and power take-off are found to a greater extent on the all-purpose type. The all-purpose tractor is designed to perform a larger variety of operations than the other two types.

Table 7.- Proportion of tractors equipped with belt pulley, power take-off and power lift equipment, by types of tractors

Equipment	Type of tractor		
	All-purpose	Standard	Track
	Percent	Percent	Percent
Belt pulley	99	98	69
Power take-off	81	51	56
Power lift	16	2	13
Number of tractors ^{1/}	503	186	16

^{1/} Based on 705 reports.

The power lift is especially convenient for many row-crop operations, such as corn cultivating and corn planting, for which the standard and track-type tractors are seldom used. The power take-off is more common than the power lift.

Nine percent of the tractors were equipped with lights for night work, although only a limited amount of nightwork was performed. Over one-half of the tractors with lights were in the Red River Valley. Only 3 percent of the tractors had self starters. Ten tractors out of the 709 were equipped with cabs. Extension rims were used on 14 percent of the tractors equipped with steel wheels. The rims in most cases were 6 inches wide.

MACHINES USED WITH TRACTORS

Along with the increased use of tractor power, has come a trend toward more and more machines that are designed for use with mechanized power exclusively. Many of these machines can be operated only by means of the power take-off. Because of this and other features of design, they generally can be used more efficiently with tractors than with horses. For some operations, it is necessary, or at least highly desirable, to have a machine that is made especially for the tractor. This is true for plowing and cultivating. Other operations can be performed satisfactorily with a tractor - using machines designed primarily for horses. Grain binders, corn binders, field cultivators, disk harrows, and mowers, are included in this group. When a farmer buys a tractor for the first time, he may use machines designed for horses with it. Replacements are usually made with specially designed tractor machines, if the replacements are to be used exclusively with the tractor.

About half of the disk harrows used with the tractors were designed for horses. It is evident that most of them were on hand when the tractor was bought. Very few horse-disks were bought after the last tractor was obtained. Most of the disks purchased in the last 5 years were those designed for tractors. The same tendency holds true for other equipment, such as field cultivators, corn cultivators, corn planters, mowers, grain binders, corn binders, and corn pickers. More grain binders designed for horses were used with tractors than any other machine. In many instances, these machines designed for horses can be bought at a considerably lower price than those designed for tractors and, as they can be used rather efficiently with tractors, are often bought instead of machines designed for tractors.

The field cultivator requires considerable power and tractor power is desirable for it. Ninety-eight of the 127 machines in use were tractor machines. About one-third of these were equipped with power lifts.

It is evident that most farmers who own tractors consider a cultivator designed for a tractor preferable to one designed for horses. Only 36 of the 371 corn cultivators in use with tractors were horse cultivators. Most of the corn cultivators were less than 5 years old. Two cultivators designed for horses had been bought new after the last tractor purchase. Only 56 of the 335 tractor machines had a power lift. Planting corn with tractors is not common on most farms; only 41 farmers used tractors for this work, and only 25 owned tractor planters.

About one farm in ten operated a mower with mechanical power. Sixty-one percent of these machines were designed for the tractor. Eighty-two percent of the tractor mowers were operated by means of the power take-off.

More grain binders were pulled by tractors than any other implement except plows. Sixty-nine percent of the grain binders pulled by tractors were horse machines, one-fourth of these having been bought within the last 5 years. Some farmers want binders that can be operated with either horse or tractor power. Others feel that the additional cost of the power take-off is not justified. Although satisfactory work can be done with a tractor and a horse-drawn binder, it is necessary to use two men—one on the tractor and one on the binder. With the power take-off, one man can handle the outfit satisfactorily under some conditions, although two are preferred, especially where the grain is heavy, tangled, or of uneven height.

Corn binders were pulled by tractors on one-fourth of the farms. Eighty-five percent of these machines were horse implements. This is explained by the fact that many of these corn binders were on the farms before the introduction of the tractor, and they, because of their short period of use each year and consequent long life, have been adapted to tractor operation.

Table 8.—Horse and tractor implements used with tractors and information on the number of such machines bought during recent years

Kind of implement	Machines designed for horses										Machines designed for tractors									
	Percentage of farms where machine was used with tractor	No.	No.	No.	No.	years: old	years: old	years: old	years: old	Purchased after last tractor	Total	No.	No.	No.	No.	years: old	years: old	years: old	years: old	With power take-off
	Percent	No.	No.	No.	No.	less: hand	or: second	or: second	or: second	Used: New	Used: All	No.	No.	No.	No.	less: hand	or: second	or: second	or: second	With power take-off
Disk harrow	87	242	5	21	122	6	7	13	262	78	132	44								
Field cultivator	22	29	2	4	8	1	1	2	93	18	27	23	31							
Corn cultivator	64	36	2	6	16	2	2	2	335	163	230	7	56							
Corn planter	7	16	3	4					25	10	14	1								
Mower	9	21	2	6	10		1	1	53	14	24	2	27							
Grain binder	96	392	32	37	130	24	19	43	175	49	101	22	133							
Corn binder	26	127	13	27	40	9	7	16	22	3	13	4	22							

WORK PERFORMED BY TRACTORS

Annual Hours of Use

Many tractors were used about 500 hours during the year, although the average hours per tractor varied with the type of tractor and the type-of-farming area of the State. The tractor used in the Red River Valley had average operations of 779 hours, compared with slightly over 500 hours for tractors in the South East area. Approximately 16 percent of the tractors in all areas were used less than 300 hours, and 20 percent more than 700 hours. Half of the tractors were used 500 hours or more.

The number of hours a tractor is used during the year depends partly upon the number of tillable acres in the farm, the amount of custom work done, the number of tractors on hand, and the available labor. Some farmers retain old tractors for belt work because of low trade-in value.

Table 9.-Frequency distribution of tractors by hours that they were operated during the year, by areas

Hours of operation	Area				
	South East	South Central	South West	West Central	Red River Valley
	Percent of tractors				
0 - 99	2	3	0	0	3
100 - 199	9	13	2	3	5
200 - 299	19	11	9	5	6
300 - 399	14	16	20	13	13
400 - 499	15	22	21	16	21
500 - 599	20	10	18	25	17
600 - 699	10	9	9	14	13
700 - 799	4	8	10	6	7
800 - 899	3	3	4	5	4
900 - 999	0	3	2	7	3
1000 - 1099	4	0	2	2	3
1100 - 1199	0	0	1	1	2
1200 and more	0	2	2	3	3
	Annual hours of tractor use				
Average	515	536	596	657	779
Maximum	1092	1328	1561	1591	1741
Minimum	65	41	120	100	40

Hours of Custom Work

Custom work represented a small proportion of the total tractor work, although more than 50 percent of the farmers reported some custom work. Only in the South East and the South Central areas was custom work as much as 10 percent of total tractor work (table 10.) The operators of larger farms usually do less custom work than those who operate small ones. Belt work constituted a slightly higher percentage of custom work than drawbar work, although there was little difference between the two. Belt work was also more significant in the southern areas than in other parts of the State.

Table 10.-Number and proportion of farmers reporting custom tractor work and the proportion that custom work was of total tractor work by areas

Item	Area				
	South East	South Central	South West	West Central	Red River Valley
Number of farmers reporting custom drawbar work	37	35	22	36	29
Number of farmers reporting custom belt work	41	46	32	30	27
Percent of all farmers reporting custom work	56	58	44	52	47
Percent of total tractor work that was custom drawbar	5	4	2	3	3
Percent of total tractor work that was custom belt work	8	9	5	4	3
Percent of total tractor work that was custom work	13	13	7	7	6

Type of Tractor and Annual Hours of Use

All-purpose tractors were used about 571 hours annually, and the standard four-wheel type about 437 hours. Drawbar work constituted 85 percent of total hours for the all-purpose tractors, and 80 percent for the standard tractors. Average annual hours of use varied considerably by areas for both types of tractors, although the proportion that drawbar work was of total work varied but little for the all-purpose tractors (table 11).

Table 11.-Average annual hours of drawbar and belt operations performed by type of tractor, and the proportion that drawbar work was of total work, by areas

Kind of operation and type of tractor	Area				
	South:	South	South	West	Red River
	East	Central	West	Central	Valley
	Number of hours				
Drawbar operations:					
Standard tractors	234	302	258	303	462
All-purpose tractors	377	407	473	590	517
Belt operations:					
Standard tractors	85	137	64	86	77
All-purpose tractors	49	80	94	80	68
Total operations:					
Standard tractors	319	439	322	389	539
All-purpose tractors	426	487	567	670	585
	Percentage of total operations that were drawbar				
Standard tractors	73	69	80	78	86
All-purpose tractors	88	84	83	88	88

Size of Tractors and Annual Hours of Use

Most of the tractors had a rated drawbar horsepower of less than 18.49. Those in the group of 12 to 18.49 horsepower predominated. The standard tractors of a rated drawbar horsepower of more than 18.49 were used more hours during the year than those of less horsepower (table 12). The all-purpose tractors of between 12 and 18.49 horsepower averaged 516 hours of drawbar work, and the group of between 18.5 and 24.99 horsepower 466 hours of drawbar work. The former group averaged 96 hours of belt work, compared with 127 for the latter group. In contrast, the standard tractor group of between 18.5 and 24.99 horsepower averaged more hours for both belt and drawbar work than did the next group of less horsepower.

Table 12. — Average annual hours of drawbar, belt, and total work performed by standard and all-purpose tractors of various drawbar horsepower

Type of tractor and kind of work	Drawbar horsepower			
	5.5 - 11.99	12.0 - 18.49	18.5 - 24.99	25.0 - 31.49
Standard:				
Drawbar hours	331	321	400	399
Belt hours	50	85	141	141
Total hours	381	406	541	540
All-purpose:				
Drawbar hours	463	516	466	---
Belt hours	51	96	127	---
Total hours	514	612	593	---

There was no significant difference in the amount of belt work as farmed by small (5.5 - 11.99 horsepower) standard and all-purpose tractors, but the all-purpose type was used 463 hours for drawbar purposes as compared with 331 hours for standard tractors.

Using Tractor to Full Capacity

When horses are used for farm work, it is not difficult to adjust the size of the power unit to the size of the load. If an operation requires four horses, then four horses can be used. If the operation requires two horses, then two horses can be used. Farm tractors do not have this flexibility. It is necessary then, insofar as practicable, to adjust the size of the load to the power of the tractor; and, in most instances, it is economical to provide a full load for the tractor. This may be done by providing a machine of the proper size, by using two or more machines at the same time, or by varying the speed at which the tractor is driven.

For certain operations, like plowing and disking, it is possible and practicable on most farms to use a machine of such size that the full power of the tractor is utilized. Fifty-six farmers reported using a combination of plow and harrow; 21 a disk and spiketooth harrow; 20 springtooth and spiketooth harrow; 17 field cultivator and spiketooth harrow; and 7 a drill and spiketooth harrow. Recent tractor models are being operated at faster speeds. These speeds are a practicable method of increasing the capacity of the tractor within certain limits. Some implements must be redesigned before they will do good work at increased speeds. Furthermore, the possibility of greater machine wear and breakage increases at the higher speeds. Specifically, it may be said that in doubling the speed of the tractor pulling a plow, the probable damage resulting from hitting a stone or other obstruction is increased four times. Such devices as release hitches and slip clutches reduce the possibilities of damage.

For many operations, such as mowing, hauling and corn planting, it is not possible to utilize the full power of the tractor on the average farm. If horses are available, it may be more economical to perform at least some of these operations with them. Although the cost per hour of operating a tractor is not greatly affected by the size of the load, it is somewhat less for a small load than for a large one. 6/ Individual tractors vary in this regard, but an average of a number of tested tractors showed that for drawbar work a load of 40 percent of the maximum rated drawbar capacity required 80 percent of the fuel per hour necessary for operation at full load. In other words, the fuel requirement per unit of work was twice as great when the tractor was operated at 40 percent capacity.

Operations Performed

Practically all of the farmers used their tractors for plowing, this job requiring 167 hours per farm during the year. The range in hours by areas was from 120 in the West Central area to 266 in the Red River Valley. Eighty-five percent of the farmers used their tractors for disking. This varied from 65 percent in the South East area to 99 percent in the South West area. (See table 13.)

In some cases, farmers do not have enough equipment to permit effective use of a tractor so they use horses. Corn planting was a tractor job on only 7 percent of the farms, and seeding grain was done on only 45 percent. Corn cultivating was done on 64 percent of the farms. Although mowing was done on only 9 percent of the farms, other haying operations were performed to a greater extent. These included pulling hayloaders and operating a sweep rake. The data indicate also that the tractor was used to operate a corn picker on about one farm in four.

Farm Hauling

Horses were used for approximately 80 percent of the hauling that was performed on the farms, but only to a very limited extent for hauling on the highways (table 14). Motortrucks were used for on-the-farm hauling to some extent, being most important in the Red River Valley. Tractors were used more commonly for on-the-farm hauling in the South East and West Central areas than in other areas. Trailers were relatively unimportant for hauling on the farm in all areas.

6/ Schwantes, A. J., "Keep the Tractor Pulling Its Optimum Load," Agricultural Engineering - Vol. 15, No. 5, May 1954, P. 170.

Table 13. — Operations performed by tractors, percentage of farms reporting each operation performed by tractors, and the average hours that tractors were used for each operation per farm in each area

Operation	Area									
	South East		South Central		South West		West Central		Red River Valley	
	Per- cent	Hours	Per- cent	Hours	Per- cent	Hours	Per- cent	Hours	Per- cent	Hours
<u>Drawbar work</u>										
Plowing	100	122	100	133	100	120	99	174	100	260
Disking	65	32	74	33	99	72	96	76	71	47
Spiketooth harrowing	71	23	66	23	93	43	91	47	85	44
Springtooth harrowing	57	21	52	16	48	19	23	7	43	20
Field cultivating	22	8	25	11	10	4	9	3	40	24
Disking and harrowing	18	7	4	0	1	0	1	0	1	0
Springtooth and harrow- ing	19	8	5	1	0	0	1	0	2	1
Field cultivating and harrowing	4	3	5	3	1	0	1	1	2	1
Miscellaneous tillage	4	2	2	0	3	2	4	1	18	18
Corn planting	4	3	2	0	7	3	9	3	8	2
Corn cultivating	62	74	62	75	86	106	73	86	23	20
Corn harvesting	32	12	39	9	14	3	27	6	28	7
Field silage cutter	2	1	2	0	1	1	0	0	5	4
Corn picking	18	23	38	53	34	36	31	29	0	0
Seeding grain	21	7	12	6	33	11	62	29	78	62
Grain harvesting	31	28	86	38	96	47	94	60	83	56
Comb. and windrowing	7	6	6	7	2	3	4	6	27	61
Mowing	7	3	1	0	8	2	12	4	16	6
Other haying operations	37	15	20	5	6	2	12	10	15	8
Potato operations	0	0	2	0	1	0	1	0	33	18
Beet operations	0	0	1	1	0	0	0	0	4	4
Manure hauling	18	20	23	18	14	11	23	8	9	4
Miscellaneous drawbar	87	16	88	14	31	13	81	18	59	17
Total		434		426		493		568		684
<u>Belt work</u>										
Silo filling	49	13	57	12	19	5	23	3	22	5
Threshing	32	31	48	43	37	40	35	43	43	53
Corn shredding	27	14	26	21	1	3	1	1	1	0
Corn shelling	2	0	5	2	11	5	15	3	2	0
Feed grinding	41	17	57	23	53	30	46	15	68	18
Wood sawing	18	4	55	8	52	7	51	8	53	7
Miscellaneous belt	9	2	5	1	55	8	36	15	21	6
Total		81		110		98		88		89
Total tractor work		515		536		596		656		773

Table 14. — Proportion of farmers reporting on-the-farm hauling with horses, motortruck, tractor, and trailer, and the proportion of the on-the-farm hauling performed by each

Item	Area				
	South	South	South	West	Red River
	East	Central	West	Central	Valley
	Percent	Percent	Percent	Percent	Percent
Farmers reporting on-farm hauling with:					
Horses	97	99	98	94	93
Motortruck	30	25	16	24	47
Tractor	44	16	23	37	16
Trailer	14	15	5	24	0
Proportion of hauling performed with:					
Horses	78	39	90	78	79
Motortruck	8	5	4	8	18
Tractor	11	3	5	10	3
Trailer	3	3	1	4	0
Total	100	100	100	100	100

Motortrucks and trailers were the most important means used by farmers in off-the-farm hauling. (see table 15.) Tractors, up to the present time, have been used but little for hauling on the highways. There is a possibility that, in the future, more off-the-farm hauling will be done with the newer, high-speed, rubber-tired tractors and trailers. Most farmers who do not own motortrucks use their own automobiles for light road-hauling and hire a motortruck on the few occasions when they have heavy road-hauling to do. In most instances, commercial motortrucks can be hired at reasonable rates, so unless a farmer has considerable road-hauling to do, he cannot afford to own a motortruck in addition to the family automobile.

Forty percent of the farmers reported that they own motortrucks. The one and one-half ton size of motortruck was most frequent, although nearly one-half were of the one ton size or smaller (table 16). More than one-half of the motortrucks in the Red River Valley and the South West areas were of the one and one-half ton size; but, in the South East and South Central areas, there were approximately as many one-half ton motor trucks as there were one and one-half ton. Much of the hauling in the Red River Valley is of a heavy type like grain hauling, whereas light operations, such as cream and milk hauling, are more important in the southern areas. The rubber-tired tractor is not expected to replace motortrucks for these types of light and heavy hauling.

Table 15. -- Proportion of farmers reporting off-the-farm hauling with horses, motortruck, tractor, and trailer, and the proportion of the off-the-farm hauling performed by each

Item	Area				
	South	South	South	West	Red River
	East	Central	West	Central	Valley
	Percent	Percent	Percent	Percent	Percent
Farmers reporting off-farm hauling with:					
Horses	0	0	9	4	15
Motortruck	63	52	59	35	85
Tractor	5	0	3	0	1
Trailer	35	48	33	66	4
Proportion performed with:					
Horses	0	0	7	3	12
Motortruck	63	52	58	34	84
Tractor	2	0	3	0	1
Trailer	35	48	32	63	3
Total	100	100	100	100	100

Table 16. -- Number of motortrucks on tractor farms and their distribution by size, by areas

Item or size group	Area				
	South	South	South	West	Red River
	East	Central	West	Central	Valley
	Number	Number	Number	Number	Number
Farmers reporting motortrucks	28	38	44	43	81
Total number of motortrucks	29	39	43	45	87
Distribution of motortrucks by size:					
1/2 ton	14	12	9	10	8
3/4 ton	2	3	1	2	6
1 ton	0	7	11	14	25
1-1/2 ton	13	15	27	18	46
2 tons or more	0	2	0	1	2

Rates of Tractor Performance

The rate at which field work is performed by tractors depends, among other things, upon the size of the tractor, the size of the machines used, and the speed at which the tractor is operated. The average acres covered per hour by some tractor-operated implements are shown by size of tractor in table 17. Group IV tractors did about twice the amount of work done by Group I tractors, regardless of the type of machine used. In other words, the proper size of machine to obtain the maximum efficiency was used with the two sizes of tractors. A considerable variation in rates of accomplishment was found in Group II and Group III tractors. Many tractors in Group III were of the older type which did not have the higher speeds and were not used with machines of sufficient size to utilize their full power at the lower speeds, so the accomplishment was less for some operations, especially in disking and harrowing.

Table 17. — Average acres covered per hour by different tractor-operated implements, by size of tractor

Operation	Size of tractor 1/			
	Group I	Group II	Group III	Group IV
	Hours	Hours	Hours	Hours
Plowing	0.9	1.1	1.3	1.8
Disking	3.2	4.2	4.1	6.9
Harrowing	7.5	8.9	8.2	13.4
Springtoothing	2.8	3.3	3.6	4.1
Field cultivating	2.7	3.2	3.4	5.3

1/ See footnote-table 2 for group rating.

The average rates of performance of other tractor-operated machines are shown in table 18. In these operations, little variation of rate of accomplishment occurred regardless of the size of the tractor used, although some difference was noted between the rates of accomplishment of horse and tractor machines. Horse machines designed to perform these operations are usually built for a slightly lower rate of operation than are tractor machines. Usually, when larger machines are used, proportionally larger amounts of work are not accomplished, for example, in cutting corn, 1.1 acres per hour are cut with a single-row binder but only 1.7 acres per hour with a two-row binder..

Table 18. — Rates of accomplishment of tractors when used with different implements

Operation	:	Size of implement	:	Average acres per hour
Seeding grain	:	8 foot grain drill	:	2.2
	:	9 foot grain drill	:	2.5
	:	10 foot grain drill	:	3.1
	:	11 foot grain drill	:	3.6
	:	12 foot grain drill	:	4.3
	:	14 foot grain drill	:	5.3
Grain harvesting	:	7 foot horse binder	:	1.9
	:	8 foot horse binder	:	2.1
	:	9 foot tractor binder	:	2.2
	:	10 foot tractor binder	:	3.0
Corn planting	:	2 row planter	:	2.0
	:	4 row planter	:	3.9
Corn cultivating	:	2 row horse cultivator	:	2.3
	:	2 row tractor cultivator	:	2.3
Cutting corn	:	1 row horse binder	:	0.9
	:	1 row tractor binder	:	1.1
	:	2 row tractor binder	:	1.7
Picking corn	:	1 row corn picker	:	0.8
	:	2 row corn picker	:	1.6
Potato planting	:	1 row planter	:	0.9
	:	2 row planter	:	1.3

Distribution of Annual Drawbar Use

The distribution of the total annual drawbar hours among various operations varied from area to area (table 19). Plowing accounted for the greater proportion of the total drawbar hours. Corn cultivating accounted for about 14 percent on all farms, but constituted as much as 21 percent of all drawbar work in the South West area. Corn cultivating, as well as other operations related to corn production, was a small proportion of the total drawbar work done in the Red River Valley. Tillage operations make up a large share of the drawbar work, about 33 percent of the total.

Table 19. — Proportion of the annual drawbar hours spent in the performance of various operations by areas

Operation	Area				
	South	South	South	West	Red River
	East	Central	West	Central	Valley
	Percent	Percent	Percent	Percent	Percent
Plowing	28	31	24	31	39
Disking	7	8	14	13	7
Other tillage	17	13	14	10	16
Cultivating corn	17	13	21	15	3
Cutting corn	3	2	1	1	1
Picking corn	5	8	7	5	—
Seeding grain	2	1	2	5	9
Grain harvesting	6	9	9	11	8
Combining grain	1	2	1	1	9
Haying	4	1	1	2	2
Hauling manure	5	4	2	1	1
Other	5	3	4	5	5
All operations	100	100	100	100	100

TRACTOR AND HORSE PRACTICES AND OPERATIONS

Length of Work Day for Tractors and Horses

The work day — the number of hours worked per day — averaged approximately one-half hour longer when tractors were used than when horses were used (see table 20). Between 50 and 60 percent of the farmers in the areas outside of the Red River Valley worked the same number of hours per day with tractors or horses. This is probably because they have certain chores that must be started at definite time of the day if they are to be done successfully. In the Red River Valley, only about one-third of the farmers worked the same number of hours with the tractor as with horses. Another one-third worked an average of two hours longer with tractors than with horses.

Table 20. -- Number of hours per day that horses and tractors were worked on tractor farms, by areas

Item	Area				
	:South : East	: South : Central	:South : West	: West : Central	:Red River : Valley
Tractor work day, average hours	: 8.9	9.0	9.2	9.5	10.7
Tractor work day, maximum hours	: 12.9	13.0	12.9	14.1	15.4
Horse work day, average hours	: 8.5	8.4	8.9	8.8	9.4
Horse work day, maximum hours	: 8.7	9.1	9.9	10.2	10.15
Percent of farms where tractor day was shorter than horse day	: 8.8	6.1	16.3	6.9	5.0
Percent of farms where tractor day was same as horse day	: 58.8	57.3	51.9	54.6	32.0
Percent of farms on which tractor day was longer than horse day	: 32.4	36.6	31.8	38.5	64.0
One hour longer	: 14.7	14.6	15.0	14.6	20.8
Two hours longer	: 14.7	14.6	13.7	16.2	29.6
Three hours longer	: 1.5	2.5	1.9	3.1	7.2
Four hours or more	: 1.5	4.9	1.2	4.6	6.4

Using Tractors a Maximum Number of Hours a Day

One hundred and seventy farmers operated their tractors during particular periods in a way that permitted them to perform the maximum number of hours of field work within a limited time (see table 21). Eighty farmers accomplished this through keeping the tractor at work during the noon hour by substituting some person for the regular operator. Other farms reported changing operators two and three times a day. In some instances, children operated tractors after school hours. A variety of operations -- plowing, disking, cultivating, harrowing, seeding, and harvesting -- were performed by these methods. Of these operations, plowing was reported most frequently, followed in order by disking and cultivating.

Table 21. — Number of methods used by farmers for operating tractors a maximum number of hours a day, frequency that methods were reported, and the operations performed, with the frequency that they were reported, by areas

Methods and operations	Area				
	South	South	South	West	Red River
	East	Central	East	Central	Valley
	Number	Number	Number	Number	Number
Methods:					
Relieve regular operator at meal time	10	9	20	27	14
Change operator two times a day	6	12	12	15	11
Operate tractor day and night	2			5	15
Change operator three times a day	2	4	1		1
Children help after school	2	1		1	
Total	22	26	33	48	41
Operations:					
Plowing	15	18	22	30	30
Disking	9	11	8	10	9
Cultivating corn	3	10	17	8	2
Grain harvesting	1	7	12	12	5
Harrowing	5	8	2	8	8
Seeding	1		1	11	6
Springtoothing	3	3	1	2	7
Field cultivating	1	2			10
Other				1	5
Total	38	59	63	82	82

Night work was not important in most areas. In the Red River Valley, however, 20 percent of the farmers used their tractors at night sometime during the year. In most instances, night work covered a period of only three or four nights during some rush period. Fifty-two operators in all areas used tractors at night for an average of 38 hours during the year. A number of night operations were reported. Plowing was performed most frequently at night, although field cultivating, grain seeding, grain harvesting, and corn picking were done to some extent. Some difficulty was encountered in getting adequate light for night operations, and a few farmers reported night work to be more fatiguing than day work.

Operations for which Tractors or Horses
Are Preferred

Because there were horses on all but 19 of the farms, most farmers were able to choose between horses and a tractor for the various farm operations. Farmers were asked to designate the operations that they preferred to perform with horses and those for which they preferred tractors, with their reasons for the preference.

Table 22. -- Operations that farmers preferred to perform with horses, the number of farmers reporting each preference, and the proportion that these farmers were of all farmers

Operations	Farmers reporting preference	
	Number	Percent
Haying	244	42
Planting corn	145	25
Hauling manure	105	18
Seeding grain	74	13
Spiketoothing	36	6
Cultivating corn	35	6
Cutting corn	16	3

Horses were preferred for many of the lighter jobs on the farm, particularly haying and planting corn (table 22). Seventeen percent considered horses a cheaper source of power than tractors for all operations (table 23). Some thought horses were more practical or more convenient in farm work. Other farmers preferred horses, because horse equipment was on the farm and they wished to wear it out.

Table 23. -- Reasons given by farmers for preferring horses for farm work, the number of farmers reporting each reason, and the proportion that these farmers were of all farmers

Reasons	Farmers reporting preference	
	Number	Percent
Cheaper	99	17
Has horse equipment	94	16
More practical	83	14
Easier	77	13
Do better and more accurate work:	47	8
Has horses	45	7
Do not pack soil	22	4

Nearly 40 percent of the operators in the South East area, 18 percent in the South Central area, 14 percent in the South West area, 17 percent in the West Central area, and 16 percent in the Red River Valley preferred tractors for all operations. This indicates that farmers think horses still have a place on their farms. Tractors were preferred definitely for the heavier work and, to a limited extent, for lighter farm work like corn planting, harrowing, seeding grain, cultivating corn, and haying (table 24). Many of these operations have only recently been performed by tractors to any extent.

Table 24. — Number and percentage of farmers expressing their preference for tractors for selected operations 1/

Operations	Farmers reporting preference	
	Number	Percent
Plowing	495	93
Disking	367	69
Harvesting grain	356	67
Corn cultivating	277	52
Spiketooth harrowing	244	46
Springtooth harrowing	224	42
Seeding grain	199	38
Field cultivating	192	36
Cutting corn	160	34
Hauling manure	155	29
Haying	149	28
Corn picking	143	27
Corn planting	128	24

1/ Based on reports from 530 farms.

Sixty percent of the farmers indicated that they thought the tractor was faster and could be used for longer hours. Twenty-nine percent felt that the tractor was more convenient, and another 21 percent said that they preferred the tractor because heat and flies did not affect it (table 25).

Table 25. -- Reasons given by farmers for preferring tractors for farm work and the proportion of the farmers reporting each reason 1/

Reasons	Farmers reporting preference	
	Number	Percent
Faster and longer hours	317	60
More convenient	155	29
Heat and flies do not affect tractor	112	21
Too hard on horses	83	16
Easier and more pleasant	83	16
Labor saving	69	13

1/ Based on reports from 530 farms.

Advantages and Disadvantages of Tractor Operation

The opinions of tractor owners with respect to the advantages and disadvantages of tractor operation are given in table 26. The fact that tractors can travel at faster speeds than horses was uppermost in the minds of those favoring tractors. Other important advantages were more efficient and economical operation, freedom from the effects of heat and flies, suitability for plowing, and saving in man labor.

Few disadvantages were reported. The cash outlay that is necessary to supply fuel and repairs, however, was often given as a disadvantage. This is a definite disadvantage during periods of low prices for farm products when farmers have difficulty in obtaining cash with which to buy fuel and supplies for the tractor. The tractor is also at a disadvantage in wet and soft ground. A team of horses can often be used on land where a tractor will mire down. Another disadvantage of tractor operation is the packing of the soil. In some areas the tracks made by tractors in the soft ground lead to soil erosion.

Table 26. -- Advantages and disadvantages of tractor operation given by farmers and the number of farmers reporting each

Advantages	Farmers reporting	Disadvantages	Farmers reporting
	Number		Number
Speed of operation	391	Cash outlay necessary	179
Economical operation	90	Wet and soft ground	46
Freedom from effect of heat and flies	73	Packs the soil	16
Suitability for plowing	56	Hard on operator	7
Saving of man labor	44	Expensive equipment	
Convenience	17	necessary	7
Weed control	16	Dangerous to operate	5
Belt work available	11	Temporary breakdowns	5
		Indivisible power	2

Reasons for Buying a Tractor

Several reasons for buying a tractor were reported by tractor owners. Over 25 percent said they could operate their farms more efficiently with tractors than with horses (table 27). Others had bought tractors because they had enlarged their farms or because they found it necessary to have more power. Many farmers bought tractors to do the heavy field work, while others bought tractors primarily to get power for belt work. During the last few years, sleeping sickness has caused the death of many horses in Minnesota. Some farmers who lost their horses replaced them with tractors.

Table 27. — Reasons given by farmers for preferring tractors for farm work and the number of farmers reporting each reason

Reasons	Farmers reporting
	Number
More efficient than horses	152
Had to have more power	127
Do heavy work	125
Cut expenses and labor	64
Belt work	58
Sleeping sickness among horses	35
Heat and flies	24
Son wanted tractor	22
Makes work easier	21
Difficulty securing labor	20
Better weed control	16
Impress neighbors	15
High price of horses	12
Good trade-in value	9
Dislikes horses	9

SUMMARY AND CONCLUSIONS

Approximately 40 percent of the drawbar horsepower available on Minnesota farms was furnished by tractors in 1938.

Most tractors in use had been bought since 1934, and the largest number were bought in 1936 and 1937. One-half of the tractors used gasoline exclusively, and about 35 percent used distillate. Kerosene has been largely replaced by gasoline and distillate in recent years. Distillate and prepared tractor fuel have been improved in quality, and their use is more satisfactory and they are found to be more dependable. Half of the tractors were used 500 hours or more per year; 16 percent were used less than 300 hours. The all-purpose tractors were used an average of 571 hours, while the standard tractors were used about 440 hours. Eighty-five percent of the hours of use was drawbar work for the all-purpose tractors, while 75 percent was drawbar work for the standard tractors.

The drawbar rating of the tractors ranged from about 6 horsepower to 61 horsepower. Tractors of 12 to 18 horsepower predominated. The farmers with 12 to 18 horsepower tractors averaged the largest number of hours use per year. The heavier tractors -- that is, those delivering over 18 horsepower at the drawbar -- tended to be used more hours per year for belt work than the lighter tractors.

Although 50 percent of the farms studied reported some custom work, it amounted to less than 10 percent of all tractor work.

Horses were used for about 80 percent of the on-farm hauling, but were of minor importance for off-farm hauling. Tractors were seldom used in either case, but with newer, high-speed, rubber-tired tractors and trailers it is possible that more of the farm hauling will be done by tractors in the future. About 60 percent of the farms had motortrucks. About 60 percent of the off-farm hauling was performed by motortrucks. Trailers were used for over one-third of such hauling.

Corn cultivating was done with tractors on about 65 percent of the farms. Grain seeding was done on about 45 percent of the farms, and grain harvesting on 90 percent. This was in addition to the heavy work like plowing, disking, field cultivating, and harrowing, in which the tractor has its greatest advantage.

Farmers preferred horses for light work like haying, planting corn, and hauling manure. Tractors were preferred for heavy work, especially plowing, disking, and spring tothing. Tractors are being used more and more for light jobs like corn planting, cultivating, and seeding. The all-purpose tractor probably is responsible in a large part for this trend. The tractor work-day averaged about one-half hour longer than the horse work-day. About 30 percent of the farmers reported tractor work in shifts, thus using the tractor to the maximum during urgent periods. Night work did not appear to be common.

Farmers considered the cash outlay necessary to obtain and operate a tractor as its major disadvantage, especially if the farmers are getting low prices for farm products. A much larger number considered the chief advantage of the tractor to be its abundant power and capacity. The increased flexibility and adaptability for many tasks has done much to win a place for the tractor in farm work.

